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Docket No.: 59031US002

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Transmittal of Provisional Application

Mail Stop Provisional Patent Application
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Inventor(s): Robert A. Yapel, Oakdale, Minnesota

Title: METHOD FOR FORMING AN EXTRUDATE HAVING SUBSTANTIALLY UNIFORM THICKNESS

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1. ☒ Enclosed is the above-identical new provisional application for patent under 35 USC § 111(b)(1). It includes:
   12 Pages of Text
   0 Sheets of Drawings
2. ☐ Enclosed is an executed Assignment to 3M Innovative Properties Company and a completed Assignment Recordation Cover Sheet.
3. ☐ This invention was made under a contract with an agency of the U.S. Government:
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4. ☒ Correspondence Address: Brian E. Szymanski
   Office of Intellectual Property Counsel
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   P.O. Box 33427
   St. Paul, Minnesota 55133-3427
5. ☒ Please charge the $160.00 filing fee under 37 CFR § 1.16(k) to Deposit Account No. 13-3723. One copy of this sheet marked duplicate is also enclosed.
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7. ☒ Enclosed is a return receipt postcard.

Respectfully Submitted,

September 17, 2003
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Patent
Docket No. 59031US002

Method For Forming An Extrudate Having Substantially Uniform Thickness

Background

In the manufacturing of coated products, it is generally desirable to attain the minimum of variation in the coating thickness. This is especially true for products for critical optical or electronic applications.

It is known in the art of coating of a liquid onto a substrate or web to accomplish the coating operation via a die type coater. Such coaters include extrusion coaters, slot coaters, fluid bearing coaters, slide coaters, slide curtain coaters, drop die curtain coaters, etc.

One of the fundamental problems associated with die type coaters is the ability to accomplish a uniform flow per unit width across the entire width of the die. All die coaters have at least one slot. Each slot has a slot width corresponding to the coated width, a slot length corresponding to the distance from the manifold cavity to the exit of the slot, and a slot height, which is the narrow dimension of the slot between the two parallel surfaces defining the slot itself. A fundamental issue in attaining the uniformity of the flow, and thus the critical uniformity of the coated product, is the ability to construct a die with the best possible uniformity of the die slot "height".

Summary of the Invention

The method of this invention is to adjust the forces that hold the die parts together to change the die slot to improve coating uniformity. For a given coating liquid and flow rates, for a well designed manifold and die slot, the best uniformity will be with a uniform die slot. For a mismatch of the manifold design to the liquid rheology and flows, a non-uniform slot might be the best for coating uniformity. The rest of this discussion will focus on making the die slot uniform, but it is understood that it is possible that another optimum profile of the die slot might be the target for other cases (such as where the rheology and flow rates are not a good match to the manifold design) and that these methods could be used to attain that optimum slot profile.

The present invention is a method for forming extrudate having substantially uniform thickness. The method includes an extrusion die having a slot and having a first die portion and a second die portion adapted to be joined by at least one releasable fastener capable. The releasable fastener is capable of applying a clamping force between the first and the second die portions. A plurality of brackets then provided. Each bracket is adapted to engage the fastener, with at least two of the brackets adapted to distribute the engaging force differently compared with one another. At least one of the brackets is selecting. The extrusion die is then assembled from the first and second die portions, using the fastener and with the fastener engaging the selected bracket, such that use of the selected bracket acts to improve the uniformity of the height of the slot. The method includes extruding flowable material through the slot.

In accordance with the invention at least one of the plurality of brackets is adapted to engage two of the fasteners simultaneously. Additionally, the assembling step is performed using at least a plurality of brackets such that that use of each of the selected brackets improves the uniformity of the height of the slot. Preferably, the height of the slot has a variation in height of about 1 percent or less along the width of the slot. At least one of the first and second die portions are adapted to engage the fasteners at particular locations, and wherein the spacing of the particular locations from the slot varies depending on the position of the particular location along the slot, such that the spacing of the particular locations from the slot is selected so as to improve the uniformity of the height of the slot after the assembling step.

Preferably, the fasteners are threaded bolts and the particular locations are complementary threaded holes. Generally, all the bolts are tightened to a predetermined torque during the assembling step.

The first and second die portions of the present invention together define a cavity and an a passageway in fluid communication with the cavity and the slot. The width of the passageway and the cavity in a direction perpendicular to the direction of the slot is generally not greater than 4.7 inches.

Detailed Description

According to a preferred embodiment of the present invention, an Offset Bracket may be used to adjust the die assembly forces to create a more uniform die slot. For purposes of the invention, the term "uniform die slot" is used to indicate that the height of the slot across the width of the die is substantially the same. The height of the slot is generally measured using conventional measurement gauges or instruments such as Capacitec Gauge from Capacitec, Ayer, MA,

Figure 1 is an example of offset bracket employed for assembling an extrusion die.

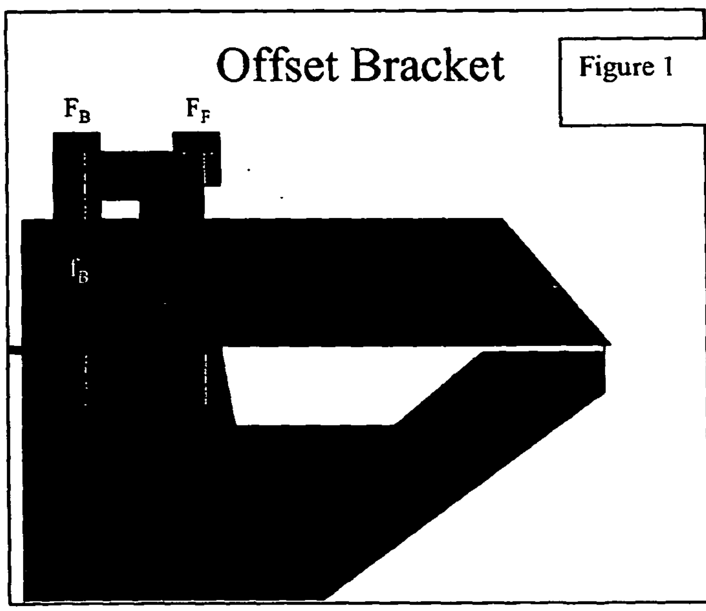


Figure 1

In certain applications where the die bolt rows are not symmetrically spaced, and when the front row of bolts is closer to the die manifold than the back row of bolts is to the die back, an offset bracket may allow use of a higher bolt torque for a uniform slot on the front row of bolts than would be utilized for a uniform slot without the offset bracket. This may be accomplished by:

a) Choosing the bolt torque for the Offset Brackets nominally according a force balance such as to the formula $T_{Front} = T_{Back}\left(\dfrac{S_B + O_F - O_B}{S_B - O_F + O_B}\right)$ where the explanation of the dimensions are as in the figure above.

b) Using any offset bracket with a coating die to attain a more uniform die slot whereby the pads directing force to the die part are not in alignment with the locations of the bolts themselves.

Another method for providing a substantially uniform die slot includes designing the die bolt spacings from the manifold and the back of the die to minimize the inherent profile in the slot under uniform die assembly bolt torques:

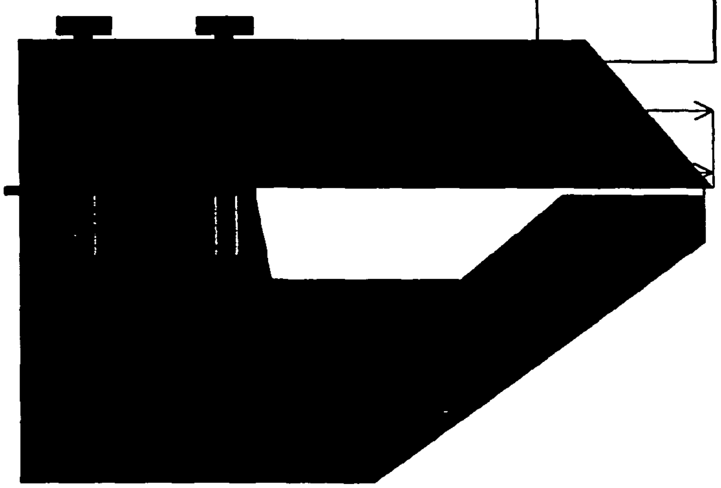
a. Increasing the dimension OF in a die design that would normally produce an inherent "Smile" slot profile to attain a more uniform die slot.
b. Decreasing the dimension OB in a die design that would normally produce an inherent "Smile" slot profile to attain a more uniform die slot.
c. Decreasing the dimension OF in a die design that would normally produce an inherent "Frown" slot profile to attain a more uniform die slot.
d. Inceasing the dimension OB in a die design that would normally produce an inherent "Frown" slot profile to attain a more uniform die slot.
e. Using two or more rows of die bolts to allow adjusting the die slot uniformity.
f. Nominally spacing the bolts on a back land symmetrically such that OF is approximately the same as OB.

In another embodiment of the present invention, it is recognized that reducing the overhang of the die top will preferably minimize the inherent "smile" profile in the die slot. An overhang is the distance from the rear of a die manifold to the leading edge of the slot in the die. Figure 2 represents an overhang on a standard die. The following table exemplifies the improved results of the present invention. The table indicates that a maximum die overhang of about 4.7 inches prevents the inherent problems associated with the longer overhangs.

Rating	Die	Total Indicated Runout, TIR With Uniform Bolt Torque microinch	Top Thick inch	Bottom Thick inch	Die Length inch	Die Depth inch	O_F	O_B	Die Top Overhang inch
[redacted]	[redacted]	[redacted]	2	4	31.75	8	[redacted]	0.94	[redacted]
[redacted]	[redacted]	[redacted]	3	6	78	12	1.38	1.00	[redacted]
[redacted]	[redacted]	[redacted]	1.5	2.25	20	6	[redacted]	0.94	[redacted]
[redacted]	[redacted]	[redacted]	1.5	2.25	9	6	[redacted]	0.94	[redacted]

Rating	Die	O_F/O_B	Ratio Overhang/Die Depth	$(\text{Overhang/Top thickness})^3$	$(\text{Overhang/Top thickness})^3/E$ Modulus Stainless Steel About 28×10^6 lbs/in^2
[redacted]		1.38	[redacted]		

Figure 2



In a preferred embodiment, offset brackets are employed in conjunction with relatively shorter overhangs to achieve superior and unexpected results in coating uniformity.

In yet another alternative embodiment of the invention, it is surprisingly recognized that by setting a pattern of non-uniform torques to the die bolts results in an optimum (uniform) die slot. Non-limiting examples of this inventive practice include:

a. For a die nominally configured with two rows of bolts along the back of the die and possibly front corner bolts on either end. Where a "smile" profile (lower slot height in the center of the die than the ends) in the slot results under uniform die assembly bolt torques, reducing the bolt torque in the front row of bolts (closest to the manifold) corresponding to the region of otherwise low die slot height.

b. For a die nominally configured with two rows of bolts along the back of the die and possibly front corner bolts on either end. Where a "smile" profile (lower slot height in the center of the die than the ends) in the slot results under uniform die assembly bolt

torques, increasing the bolt torque in the back row of bolts (closest to the back of the die, furthest from the manifold) corresponding to the region of otherwise low die slot height.

c. For a die nominally configured with two rows of bolts along the back of the die and possibly front corner bolts on either end. Where a "smile" profile (lower slot height in the center of the die than the ends) in the slot results under uniform die assembly bolt torques, increasing the bolt torque in the front row of bolts (closest to the manifold) corresponding to the region of otherwise high die slot height.

d. For a die nominally configured with two rows of bolts along the back of the die and possibly front corner bolts on either end. Where a "smile" profile (lower slot height in the center of the die than the ends) in the slot results under uniform die assembly bolt torques, decreasing the bolt torque in the back row of bolts (closest to the back of the die, furthest from the manifold) corresponding to the region of otherwise high die slot height.

e. For a die nominally configured with front corner bolts on either end. Where a "smile" profile (lower slot height in the center of the die than the ends) in the slot results under uniform die assembly bolt torques, increasing the bolt torque in the front corner bolts corresponding to the region of otherwise high die slot height near the corresponding die end.

f. For a die nominally configured with two rows of bolts along the back of the die and possibly front corner bolts on either end. Where a "frown" profile (higher slot height in the center of the die than the ends) in the slot results under uniform die assembly bolt torques, increasing the bolt torque in the front row of bolts (closest to the manifold) corresponding to the region of otherwise high die slot height.

g. For a die nominally configured with two rows of bolts along the back of the die and possibly front corner bolts on either end. Where a "frown" profile (higher slot height in the center of the die than the ends) in the slot results under uniform die assembly bolt torques, decreasing the bolt torque in the back row of bolts (closest to the back of the die, furthest from the manifold) corresponding to the region of otherwise high die slot height.

h. For a die nominally configured with two rows of bolts along the back of the die and possibly front corner bolts on either end. Where a "frown" profile (higher slot height in the center of the die than the ends) in the slot results under uniform die assembly bolt torques, decreasing the bolt torque in the front row of bolts (closest to the manifold) corresponding to the region of otherwise low die slot height.

i. For a die nominally configured with two rows of bolts along the back of the die and possibly front corner bolts on either end. Where a "frown" profile (lower slot height in the center of the die than the ends) in the slot results under uniform die assembly bolt torques, increasing the bolt torque in the back row of bolts (closest to the back of the die, furthest from the manifold) corresponding to the region of otherwise low die slot height.

j. For a die nominally configured with front corner bolts on either end. Where a "frown" profile (higher slot height in the center of the die than the ends) in the slot results under uniform die assembly bolt torques, decreasing the bolt torque in the front corner bolts corresponding to the region of otherwise low die slot height near the corresponding die end.

k. In any die with two or more rows of bolts, increasing the torque in the bolts of the front row (closest to the manifold) to decrease the die slot in the vicinity of the die bolt to attain a more uniform die slot.

l. In any die with two or more rows of bolts, decreasing the torque in the bolts of the front row (closest to the manifold) to increase the die slot in the vicinity of the die bolt to attain a more uniform die slot.

m. In any die with two or more rows of bolts, increasing the torque in the bolts of the back row (closest to the back of the die, furthest from the manifold) to increase the die slot in the vicinity of the die bolt to attain a more uniform die slot.

n. In any die with two rows or more of bolts, decreasing the torque in the bolts of the back row (closest to the back of the die, furthest from the manifold) to decrease the die slot in the vicinity of the die bolt to attain a more uniform die slot.

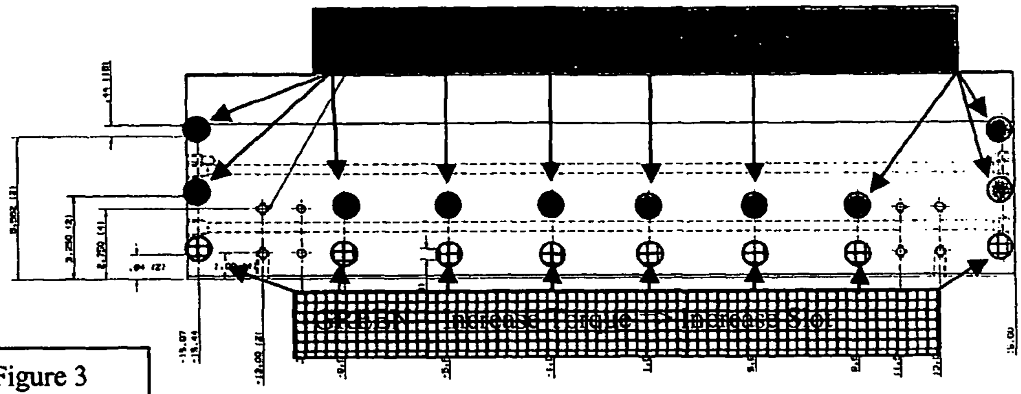


Figure 3

It is understood that to get the best results, the die assembly bolt threads and the threads in the die parts must be clean, in good condition, and possibly lubricated with an appropriate lubricant or anti-seize compound. Also, it is advantageous to use die parts fabricated to be as flat as possible. If a shim is utilized, then a more uniform shim is desirable such as described in U.S. Application Serial No. 10/027,763, herein incorporated by reference.

This invention is a large improvement over the standard methods of fabrication and use of slot type coating bars. It allows a several fold improvement in crossweb uniformity in these coating methods. This is a high impact improvement capability facilitating production of optical and other critical products.

Examples

Coating dies has a tendency towards a "Smile" (smaller slot height in the middle than the ends) in the slot under uniform torque of the die assembly bolts The slot height was measured using a Capacitec Gage. The results of the measurements are plotted in the following graph included below.

Offset Brackets were fabricated to make the force acting on the die top symmetric and the same on the front and back bolt rows. To accomplish this, an appropriate bolt torque on front and back bolts was chosen. For this, assuming that bolt force is proportional to torque, $f_F = f_B$, $f_F + f_B = F_F + F_B$, that we choose to have the new bracket pad offset from the

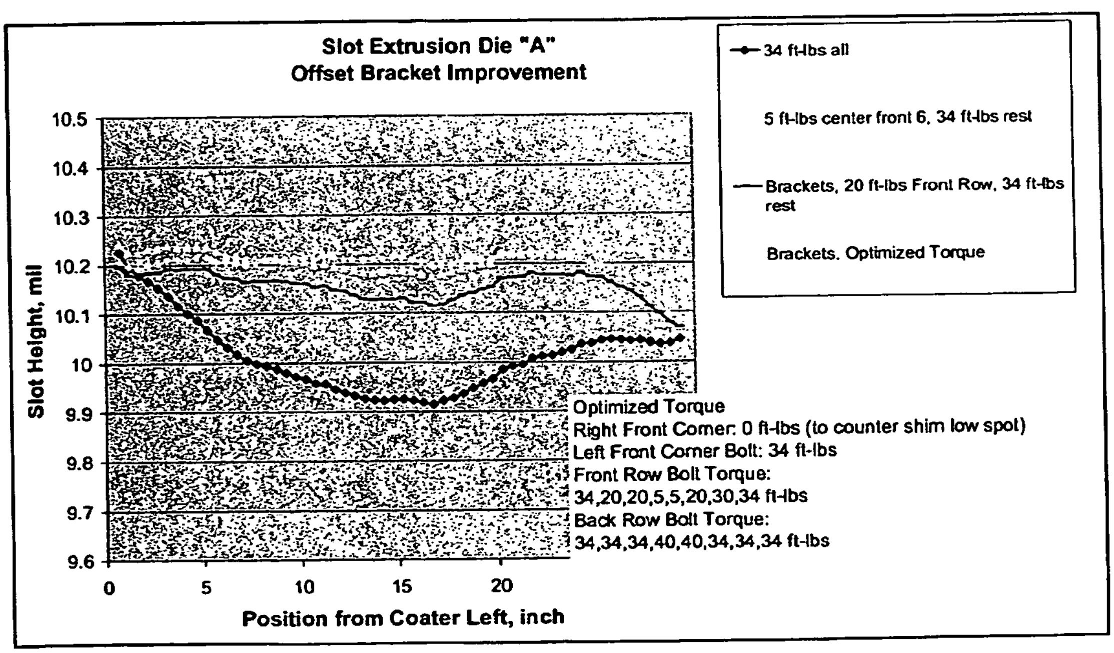
manifold the same as the back bolt space from the back of the die O_B, and that the forces acting to rotate the bracket balance $F_F(S_B) = f_F(S_B - O_B + O_F)$

then

$$T_{Front} = T_{Back}\left(\frac{S_B + O_F - O_B}{S_B - O_F + O_B}\right)$$

For a standard slot extrusion die as shown in Figure 3, having dimensions of : S_B=1.896 inch, O_F=0.432 inch, O_B=0.938 inch, so for T_{back}=34 ft-lbs, then T_{front}=19.7 ft-lbs. Due to the accuracy of the Torque Wrench, we used Tfront=20 ft-lbs was used.

The results indicate that the slot can be made flat (removing the "Smile") by using thc brackets at the calculated torques. (See graph above and in the Optimized Bolt Torque section). This means, brackets are suitable at a larger bolt torque (20 ft-lbs) and resulting in larger assembly force for better sealing and more consistent die assembly with the brackets than by just using a lower torque (about 5 ft-lbs) on the front row center 6 bolts.



Reasonable modifications and variations are possible from the forgoing description without departing from either the spirit or scope of this invention.

What is Claimed is:

1. A method for forming extrudate having substantially uniform thickness comprising:

providing an extrusion die having a slot and having a first die portion and a second die portion adapted to be joined by at least one releasable fastener capable of applying a clamping force between the first and the second die portions;

providing a plurality of brackets, each adapted to engage the fastener, with at least two of the brackets adapted to distribute the engaging force differently compared with one another;

selecting at least one bracket;

assembling the extrusion die from the first and second die portions, using the fastener and with the fastener engaging the selected bracket, such that use of the selected bracket acts to improve the uniformity of the height of the slot; and

extruding flowable material through the slot.

2. The method according to claim 1 wherein at least one of the plurality of brackets is adapted to engage two of the fasteners simultaneously.

3. The method according to claim 1 wherein the assembling step is performed using at least a plurality of brackets such that that use of each of the selected bracket acts to improve the uniformity of the height of the slot.

4. The method according to claim 1 wherein the height of the slot has a variation in height of about 1.5 percent or less along the width of the slot.

5. The method according to claim 1 wherein at least one of the first and second die portions are adapted to engage the fasteners at particular locations, and wherein the spacing of the particular locations from the slot varies depending on the position of the particular location along the slot, such that the spacing of the particular locations from the slot is selected so as to improve the uniformity of the height of the slot after the assembling step.

6. The method according to claim 5 wherein the fasteners are threaded bolts and the particular locations are complementary threaded holes.

7. The method according to claim 6 wherein all the bolts are tightened to a predetermined torque during the assembling step.

8. The method according to claim 1 wherein the first and second die portions together define a cavity and a passageway in fluid communication with the cavity and the slot, wherein the width of the passageway and the cavity in a direction perpendicular to the direction of the slot is not greater than 4.7 inch.

9. The method according to claim 1, wherein the fasteners along the length of the die are placed in at least two rows, and the assembly forces are varied in the fasteners of each of said rows to provide a substantially uniform die slot height.

10. A method for forming extrudate having substantially uniform thickness comprising:

providing an extrusion die having a slot and having a first die portion and a second die portion adapted to be joined by a plurality of releasable fasteners capable of applying a clamping force between the first and the second die portions;

assembling the extrusion die from the first and second die portions using the fasteners, wherein the fasteners along the length of the die are placed in at least two rows, and the assembly forces are varied in the fasteners of each of said rows to provide a substantially uniform die slot height; and

extruding flowable material through the slot.

11. A method for forming extrudate having substantially uniform thickness comprising:

providing an extrusion die having a slot and having a first die portion and a second die portion adapted to be joined by at least one releasable fastener capable of applying a clamping force between the first and the second die portions, wherein the first and second die portions together define a cavity and a passageway in fluid communication with the cavity and the slot,

wherein the width of the passageway and the cavity in a direction perpendicular to the direction of the slot is not greater than 4.7 inch to improve the uniformity of the height of the slot;

assembling the extrusion die from the first and second die portions, using the fastener; and

extruding flowable material through the slot.

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